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Using K-12 Mathematics Curriculum Materials in Teacher Education: Rationale, Strategies, and Preservice Teachers' Experiences[1]

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Engagement with K-12 curriculum materials has long been utilized as a successful professional development strategy for inservice teachers, but only recently has it emerged as a valuable preservice teacher education activity. With the availability of Standards-based mathematics curriculum materials, teacher educators have unique opportunities to challenge preservice teachers' conceptions of mathematics teaching and learning through the use and analysis of curriculum materials. This paper provides a rationale and proposes strategies for adapting K-12 curriculum materials for preservice mathematics teacher education, and describes preservice elementary teachers' experiences learning with middle-school curriculum materials in undergraduate mathematics courses.

Teachers engaged in current mathematics education

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reforms attempt to establish classrooms in which students engage actively and cooperatively in exploration and discussion to solve rich problems and reason mathematically (National Council of Teachers of Mathematics [NCTM], 1989, 2000). To support the vision of mathematics instruction presented in the 1989 *Standards* document, a dozen or more federally-funded projects developed novel curriculum materials during the 1990s. Students' problem-solving abilities and conceptual understandings of mathematics appear to be impacted positively by the use of these materials (Senk & Thompson, 2003). Because they are a source of mathematically rich problems and instructional activities, these materials may also give rise to potent opportunities for *teachers* to learn (Ball & Cohen, 1996). Although many reports have illustrated the challenges faced by teachers when implementing *Standards*-based materials (Frykholm, 2004; Lambdin & Preston, 1995; Lloyd, 1999; Manoucheri & Goodman, 1998; Wilson & Lloyd, 2000), research also has offered images of teachers learning about mathematics and pedagogy while using these materials (Lloyd, 2002a; Remillard, 2000; Van Zoest & Bohl, 2002).

The challenges of curriculum implementation, together with the potential of curriculum materials to promote and support teacher learning, suggest that preservice teachers may benefit from early experiences with *Standards*-based K-12 curriculum materials. Engaging teachers with textbooks and curriculum materials is a commonly used and effective professional development strategy for inservice teachers (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). Increasingly, teacher educators are using K-12 curriculum materials, particularly *Standards*-based materials, in the preparation of preservice teachers (Frykholm, 2005; Lloyd, 2002b; Lloyd & Behm, 2005; Tarr & Papick, 2004). This paper provides a rationale for using such materials in preservice mathematics teacher

education, proposes strategies for using mathematics curriculum materials in courses for preservice teachers, and describes preservice elementary teachers' experiences using middle-school curriculum materials in undergraduate mathematics courses.

Rationale for the Use of Curriculum Materials in Teacher Education

Many preservice teachers possess weak knowledge and narrow views of mathematics and mathematics pedagogy. Because such conceptions deeply affect the learning-to-teach process, teacher educators are faced with the task of creating opportunities for preservice teachers to develop useful, dynamic conceptions of mathematics and pedagogy. As described in the following sections, experiences with curriculum materials have potential to challenge preservice teachers' conceptions of mathematics, teaching and learning, and curriculum so that learning (and re-learning) in these areas may occur.

Learning Mathematics

A primary aim of engaging preservice teachers with K-12 curriculum materials is to facilitate the learning or re-learning of the school mathematics curriculum. For preservice teachers, this learning involves revisiting mathematical ideas to include conceptual or relational understandings (Skemp, 1987), as well as exploring unfamiliar curricular areas, such as probability, statistics, and discrete mathematics, that are integral to the *Standards'* vision (NCTM, 1989, 2000). Preservice teachers' views of mathematical activity also need to be developed so that these views include *mathematics* as a dynamic, evolving body of knowledge (Ernest, 1991) and *understanding* as the capacity to use mathematics to reason, to communicate, and to pose and solve meaningful problems (Hiebert et al., 1996).

Textbooks that have been written for mathematics courses for preservice teachers tend to be traditional in design, essentially "telling" preservice teachers what they need to know. In contrast, reform-oriented curriculum materials contain diverse problems and activities that challenge preservice teachers and require them to develop and test their own mathematical ideas in the social setting of the classroom. Use of curriculum materials has potential to offer preservice teachers experiences "in doing mathematics—in exploring, guessing, testing, estimating, arguing, and proving . . . They should learn mathematics in a manner that encourages active engagement with mathematical ideas" (Mathematical Sciences Education Board & National Research Council, 1989, p. 65). As preservice teachers revisit mathematical content from new perspectives, they begin to translate the knowledge developed as students of mathematics into pedagogical content knowledge - knowledge of mathematics *for teaching* (Shulman, 1987).

Learning about Mathematics Teaching and Learning

Another purpose of using curriculum materials in teacher education is to promote the view that mathematics is learned through an active, social process of construction rather than through transmission (Cobb, 1995; Davis & Maher, 1990; von Glasersfeld, 1984). As preservice teachers engage in mathematical activities presented in curriculum materials, examination of their own learning processes may help them recognize the significance of learning that can occur during inquiry-based, student-centered activities. Research has indicated that a teacher's views about how students engage in mathematical activity and learn may greatly inhibit (or support) inquiry-based instruction (Fennema et al., 1996). In many cases, teachers' self-efficacy is rooted in models of learning that are not consistent with current reforms -- teachers have

traditionally felt most self-efficacious when they tell students what they need to know (Smith, 1996). Preservice teachers' experiences with curriculum materials encourage them to explore, conjecture, and reason about mathematical problems and situations – experiences that have potential to empower them as learners and teachers of mathematics.

Learning about Curriculum

Preservice teachers can also undertake critical analyses of the mathematical content and instructional designs of curriculum materials. Through analysis of mathematics curriculum materials, preservice teachers have opportunities to develop sophisticated views of curriculum (Ball & Cohen, 1996; Ben-Peretz, 1990; Lloyd & Behm, 2005). Ben-Peretz (1990) contends that curriculum "elaboration and change may be considered a cardinal component of [teachers'] professional activities" (p. 110) and suggests that particular curricular capabilities and understandings are needed. Analysis of issues that underlie curriculum development, termed "choice points" by Connelly (1972), can make mathematical and instructional features of curriculum materials apparent to preservice teachers. For example, it is important for preservice teachers to recognize that there are many ways that curriculum developers might approach instruction about a particular mathematical topic. Embedded in such approaches are different philosophies of teaching and learning that fulfill a variety of cultural and social purposes. Experiences with curriculum analysis can prepare preservice teachers to make reasoned decisions about the selection and adaptation of instructional materials in their future mathematics classrooms.

Strategies for Using Curriculum Materials in Teacher Education

Reform-oriented curriculum materials can be used in a

variety of ways and for a variety of purposes in mathematics and methods courses for teachers.[i] Table 1 presents a selection of strategies for using curriculum materials for different purposes in preservice teacher education. Perhaps the most natural way to use curriculum materials is to engage preservice teachers in exploring mathematical problems and activities with the goal of learning or re-learning subject matter. Although curriculum designers wrote these materials for K-12 students, the mathematics in the materials can be challenging, even for preservice teachers. Many aspects of the content are unfamiliar to preservice teachers, both because conceptual aspects of mathematics are emphasized and because some of the content is relatively new to the school curriculum (e.g., probability, statistics, and discrete mathematics).

Because mathematical ideas are explored in reform-oriented ways (for instance, in real-world contexts, through small group discussions, with graphing calculators) in these curriculum materials, many teaching and learning issues can be explored. For instance, work with teachers' editions (which include descriptions of possible student responses or work) to plan instructional activities can help preservice teachers think about the processes through which students develop understandings during particular classroom activities. Due to the rich mathematical content and innovative instructional design of the materials, opportunities for the integration of content and pedagogy abound (Ball, 2000). In fact, many of the strategies in Table 1 can be used to accomplish multiple purposes related to mathematics, teaching and learning, and curriculum.

Adapting K-12 Materials for Use by Preservice Teachers

As teacher educators think about using curriculum materials with preservice teachers, it is important to attend carefully to the selection and adaptation of materials. Tasks and activities originally written for K-12 students must be

selected and adapted in ways that are relevant and useful to preservice teachers. Mathematics problems that provide learning opportunities for children are not necessarily productive or educative problems for consideration by teachers. The greatest potential for teachers' learning about mathematics is through engagement with tasks that are mathematically challenging, emphasize conceptual understandings, address common misconceptions, and have potential to illustrate connections among concepts, representations, and real-world contexts. Tasks with greatest potential to illustrate or question important teaching and learning issues are those with multiple solution strategies, technology use, meaningful real-world contexts, problem-based learning, experimentation, and investigation.

Once tasks or activities have been selected, adaptations must be made to suit these materials to *teacher* learning. Adaptations must go beyond preservice teachers' use of the materials *as students* but also must include preservice teachers' engagement with the materials *from a teaching perspective.* For example, a high school student would not typically study the same mathematical concept using two different curriculum units, but preservice teachers might (e.g., for comparison purposes). Uses of curriculum materials in preservice teacher education, such as those listed in Table 1, are likely to be most productive if instruction begins with a focus on the mathematics of the curriculum materials (Lloyd & Behm, 2005; see also Hill & Ball, 2004) so that preservice teachers' pedagogical views and decisions can be firmly based in knowledge and reasoning about the mathematics they will be teaching.

An Example of a Curriculum-Based Strategy

A detailed illustration from my own use of K-12 curriculum materials with preservice teachers in mathematics courses over the past eight years may be

helpful to other teacher educators. Selected units from several middle-school curriculum projects comprise the main texts for these courses.[ii] Preservice teachers spend extended periods of time in class using the curriculum units to learn or re-learn mathematical subject matter (number concepts, probability and statistics, discrete mathematics, and geometry) and consider related pedagogical issues.

The example shared in this section involves two middle school units, *Prime Time* (Lappan, Fey, Fitzgerald, Friel, & Phillips, 1996) and *Reflections on Number* (Mathematics in Context [MiC], 1998), which both present innovative activities related to number-theoretic ideas such as factors, multiples, divisors, and primes. Although the books contain distinctly different activities, they have one major mathematics problem in common. The Locker Problem from *Prime Time* and the Changing Positions Problem from *Reflections on Number* involve the idea that perfect squares are the only numbers with an odd number of factors. The Locker Problem reads,

> There are 1000 lockers in the long hall of Westfalls High. . . . The lockers are numbered from 1 to 1000. . . . Student 1 runs down the row of lockers and opens every door. Student 2 closes the doors of lockers 2, 4, 6, 8, and so on to the end of the line. Student 3 changes the state of the doors of lockers 3, 6, 9, 12, and so on to the end of the line. (The student opens the door if it is closed and closes the door if it is open.) Student 4 changes the state of the doors of lockers 4, 8, 12, 16, and so on . . . until all 1000 students have had a turn. When all the students are finished, which lockers are open? (pp. 58-60)

In the Changing Positions Problem in *Reflections on Number*, numbered students stand up and sit down in a way similar to lockers being opened and closed in the Locker Problem. Although these problems are similar and are

presented as key problems in the two curriculum units, the problems play different roles in the development of mathematical ideas in the two units. In *Prime Time*, the Locker Problem appears at the end of the unit after students have developed the mathematical ideas needed to solve it. In contrast, the Changing Positions Problem appears early in *Reflections on Number* as an initial experience with the main mathematical ideas that are explored in the unit.

These problems (and the curriculum units containing them) provide excellent contexts for preservice teachers to develop new mathematical and pedagogical understandings. The problems are challenging, demand that learners develop and apply conceptual understandings, have interesting real-world contexts, and involve important concepts and representations of those concepts. After the preservice teachers in my mathematics course work on most of the problems and activities in *Prime Time* and *Reflections on Number*, they reflect on their learning and analyze the curriculum materials. Table 2 offers some of the questions about the Locker Problem and the Changing Positions Problem to which the preservice teachers respond, as well as examples of two preservice teachers' responses. As Annika and Joy's[iii] responses suggest, curriculum analysis can follow naturally from preservice teachers' engagement with the mathematics problems in the curriculum materials. Distinctions between different reform-oriented curricula (and similarly, between reform and traditional curricula) provide rich opportunities for preservice teachers to explore, and possibly experience, multiple approaches to mathematical subject matter and mathematics pedagogy.

Preservice Elementary Teachers' Experiences

This section supplements the strategies presented in the previous section by discussing preservice elementary teachers' experiences using *Standards*-based middle school

curriculum materials. Most preservice elementary teachers are surprised to find that working with the middle-school curriculum materials as learners of mathematics can be challenging. Preservice teachers quickly become aware that the curriculum materials are different from the mathematics materials and textbooks they have used in the past. They are impressed with the curriculum materials' focus on multiple solutions to problems and emphasis on why particular methods and procedures work and make sense. For example, as preservice teachers attempt to determine how lattice multiplication works, they also think about the role of partial products in conventional multiplication algorithms and why those multiplication algorithms make sense.

One preservice teacher (Meg) expressed differences that she observed between the middle-school curriculum materials and more traditional mathematics textbooks:

> A typical textbook has a lesson and a group of questions. What we have is similar but it doesn't teach what we're learning. . . It's more questions and a lot of explanations. They'll ask questions and then "Why? Why this?" or "What could be different?"

The unfamiliar format of the curriculum materials can initially present frustration for some preservice teachers who desire more guidance from a textbook. As Jessica expressed,

> I like to have an explanation and then maybe an example or two and then some problems. . . . Some of the books just say "do this problem" and you don't really have any basis for what you're doing, or where to start.

Over time, most preservice teachers come to appreciate the place of investigation and discussion in the development of mathematical understanding. To varying degrees, preservice teachers' levels of comfort appear to increase as

they accumulate experiences solving challenging mathematics problems from the materials, particularly with the support and collaboration of classmates.

Preservice teachers also seem to benefit from course activities that draw their attention to pedagogical issues through reflection on and analysis of the mathematical work they are doing. However, opportunities for learning about pedagogy and curriculum do not occur only during course assignments that explicitly focus on those areas. During class discussions about mathematical questions and ideas, preservice teachers themselves frequently raise issues related to students' learning through the activities presented in the curriculum materials, the design or philosophy of the materials, and ways that teachers would use the materials (or similar materials) with children.

Consider a class discussion that followed preservice teachers' work on an investigation in *Reflections on Number* (MiC, 1998) in which the teachers had to assume the role of a tutor who helps a child, Harvey, with a mathematics problem related to division with zero. The investigation begins,

> During one tutoring session, you say to Harvey, "For every multiplication problem, there are related division problems. For example, you can take $3 \times 7 = 21$ and write $21 \div 3 = 7$." . . . Next, you ask Harvey to write a division statement for the following situation: "You have six stickers, and you share them with no one." Harvey smiles, "I know that! I have six stickers and I share with nobody. The division statement is $6 \div 0 = 6$. I am sharing with nobody, so I have all six stickers." (p. 28)

During our class discussion about division involving zero, the preservice teachers commented extensively about the role of the tutor (and the text, to a lesser extent) in teaching about this idea:

Beth: I just want to say that I was personally offended that I was being a tutor but they didn't explain the problem to the kid right. Wasn't it something about sharing something with only himself? And he says if you divided it with no one? If you didn't share it with anyone, then I, the tutor, would have been like, "Well, don't forget yourself – you're *one*." And then there would have been none of this confusion. You're not dividing by zero because you're *one*, so it's six divided by one, which is six! Why didn't he [the tutor] just tell him [the student]? (Sighs, class laughs)

Instructor: Well, what do you think of the tutor in the problem? (to the rest of the class)

Several preservice teachers: Bad. Weak. (Some teachers shrug their shoulders.)

Nicole: The tutor didn't explain. . . . There was no explanation at all that I could find in that (pointing at the *Reflections on Number* book on her table).

After the class had shifted attention away from the tutor and back to the idea of "6 divided by 0," Jessica introduced some additional comments that turned the discussion again to Beth's idea that the tutor should have told Harvey that he had forgotten to include himself.

Jessica: To put myself in a kid's point of view, I would think that six divided by zero is six. You have six, you divide it by nothing, you have six. I think Harvey's explanation for his age made perfect sense and I was like, "Well how do you say it's not?" And the tutor used a calculator. That's not a great learning tool. It still didn't tell him *why*. He [the tutor] is just like, "Oh, it doesn't work. The calculator says it doesn't work so it doesn't work."

Cathy: Six times zero would be zero and not six. I mean, it only checks one way, which may confuse them, like she [Jessica] said. Explaining would

help!

Beth: She [the tutor] should have said, "Well, you're splitting it by no one but you have it yourself, so it's really six divided by one."

In this short excerpt, preservice teachers made comments about a wide range of mathematical and pedagogical issues, including the lack of direct explanation by the tutor in the investigation, appropriate use of calculators in teaching and learning, mathematical considerations related to division and its inverse, ways for teachers to approach children's learning. Conversations like this one offer teacher educators invaluable opportunities to elicit and discuss teachers' struggles and questions about teaching and learning that relate to mathematical work with curriculum materials.

Conclusions

Given the demands of the current reform movement in mathematics education, teacher educators should consider seriously the powerful role that *Standards*-based curriculum materials can play in the preparation of future teachers. Experiences with innovative curriculum materials may compel preservice teachers to recognize the significance of the learning that can occur during inquiry and student-centered activities. Moreover, explicit emphasis in teacher education may enable beginning teachers to use textbooks, curriculum materials, and other resource materials to teach themselves and their students. If teachers can learn to use their textbooks for their own personal development, then they may be prepared to learn from and deal productively with the types of materials that will continue to emerge in school settings in the future.

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[i] This manuscript focuses on the incorporation of curriculum materials into teacher education coursework. Another promising context for preservice teachers' learning with curriculum materials, beyond the scope of this chapter, is student-teaching placements in the classrooms of teachers implementing innovative materials (see Van Zoest & Bohl, 2002).

[ii] Selected curriculum units correspond to the mathematical emphases typical to college mathematics textbooks for preservice elementary teachers.

[iii] All names of preservice teachers are pseudonyms. Unless otherwise noted, quotes from preservice teachers are taken from transcripts of interviews conducted outside of class.

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Table 1: *Sample Strategies*

For Learning About …	**Sample Strategies for Using Curriculum Materials [CMs]**
Mathematics	Solve mathematics problems and conduct particular experiments and investigations from selected CMs
	Compare and contrast different methods for solving similar problems and analyze why different methods make sense
	Create concept maps to identify connections among the different mathematical ideas explored in a particular unit
	Compare representations and definitions of particular mathematical ideas (e.g. fractions, functions) in reform-oriented CMs and more traditional textbooks, with analysis of the mathematical and pedagogical implications of the differences
Teaching and Learning Mathematics	Trace the development of one mathematical concept through a curriculum series (e.g., How is the concept of *variable* developed in the MiC curriculum?)
	For a particular mathematical topic, compare the mathematical approaches of different CMs to reform recommendations (e.g. NCTM *Standards)*

	for that topic
	Examine a variety of student work on mathematics problems from the CMs to develop hypotheses about students' learning and implications for teaching
	Use the teacher's guide of a CM unit to plan and teach a lesson to peers (preservice teachers)
Curriculum	Compare and contrast the ways that two different CM units approach the teaching and learning of the same mathematical topic
	Identify the philosophies underlying different curriculum projects and relate them to the ways the CMs position students and the teacher in the learning process
	Watch a video of a classroom in which a particular lesson from CMs is taught, and (with the assistance of the teacher's guide) identify ways in which the teacher adapted the recommendations of the CMs
	Adapt traditional textbook lessons to develop technology-rich, inquiry-oriented lesson plans and examine the differences and similarities in the range of lessons developed by preservice teachers

Table 2: *Sample Questions and Responses*

Questions about the Locker Problem and the Changing Positions Problem	**Sample Responses from Two Preservice Elementary Teachers (from written assignments)**
How are these two problems related? What features of the two problems are similar? What features are different?	• The Locker Problem and the Changing Positions Problem were similar in that they dealt with the idea of perfect squares in a critical thinking way. They both used a game format to make it more appealing while at the same time learning the concept. The difference was that in the Changing Positions Problem, the student actually took part in it in a classroom setting. [Annika] • The Changing Positions and Locker problems were related because they both used factors. The students with a card that had a factor that was called by the teacher sat or stood. The students in the school shut or opened the lockers that they were factors of. [Joy]
How did these problems (and/or the curriculum units they are in) engage you in thinking about each of the following mathematical ideas: factors, factor pairs, and square numbers?	• I think that factors were addressed clearly in *Reflections on Numbers* because they approached it with several different methods. They used graphs and factor trees to demonstrate ways of finding the factors. This gives the students options in finding the best way to solve the problem for themselves. The *Prime Time* book simply used word problems but I found that they didn't give methods in finding the answers as well as the other book did. [Annika] • *Prime Time* addressed factors most directly with the factor game. *Reflections on Number* addressed factors most directly using prime factors with factor trees. Both ways, the game and the factor trees, clearly show the factors of a number. The game is beneficial because students get to interact with other students to try and win the game.

	The factor trees are different from the game because students have to find the factors themselves, while in the game the factors are already there and the students just have to circle them. [Joy]
Did you find the context for one of the problems more accessible than the other?	• I found the Changing Positions problem easier to solve because it was one that you could physically partake in. [Annika] • I thought the Changing Positions problem was easier to solve because a classroom of students is less than 1000. Even though you didn't have to go all the way up to 1000 in the Locker Problem, it was easier knowing in the Changing Positions Problem that you could get the pattern with a small number. [Joy]
Why do you think the Changing Positions Problem appears early in *Reflections on Number* but the Locker Problem appears at the end of *Prime Time*? Which placement makes more sense to you?	• I think that the two books placed the problems in different places in the text depending on how they introduced the concept. If I were to teach this, I may use the problem in the beginning to introduce the topic and make it interesting. Then I would follow up with problems and discussion involving the pattern that occurred. [Annika] • I really don't know why an author would choose this order unless the books are intended for different grade levels. I would prefer to end with this type of problem because it requires a lot of skills of pattern solving with factors and multiples. I think the students should have lots of practice with these concepts before trying to solve a problem as tricky as this. [Joy]